Recent Activities of the EUV Resist Research and Development at Center for EUVL

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Outline

1. Introduction

2. Chemical reaction analysis for increasing acid generation efficiency of the EUV resist using SR absorption spectrocopy

3. EUV Interference Lithography

4. Contamination evaluation using high power EUV source

5. Summary

Research Activities at Center for EUVL, University of Hyogo

1984 Extreme Ultraviolet Lithography research is started at NTT Atsugi Lab. (Hiroo Kinoshita's Group)

1994 First International Workshop in Japan

1996-1998 56 nm L/S pattern was demonstrated first in the world by the exposure tool (ETS-1) at NewSUBARU BL3 beamline (Collaboration with Nikon and Hitachi)

1998-2002 60 nm L/S pattern and 40 nm isolated line in the full field exposure was demonstrated the first in the world utilizing the updated ETS-1 at NewSUBARU BL3 beamline (Collaboration with ASET, Resist and Mask Companies)

2001 Full field exposure was demonstrated first in the world at NewSUBARU BL3 beamline

2002-2007 EUV Microscope for mask defect inspection, JST, CREST

2004-2009 Resist and mask collaboration work with Selete

2009-2012 EUV Interference Lithographic Tool for 1X nm, JSPS

2008-2013 EUV Microscope for mask defect inspection, JST, CREST

2010- Resist and mask collaboration work with EIDEC, Resist and Mask Companies, Universities

2010- Center for EUVL was established at University of Hyogo, to accelerate EUVL technology for the practical usage.

2012- SR absorption spectroscopy method was applied with the more fundamental work using EUV exposure to develop the EUV resist for 1x nm node and below.

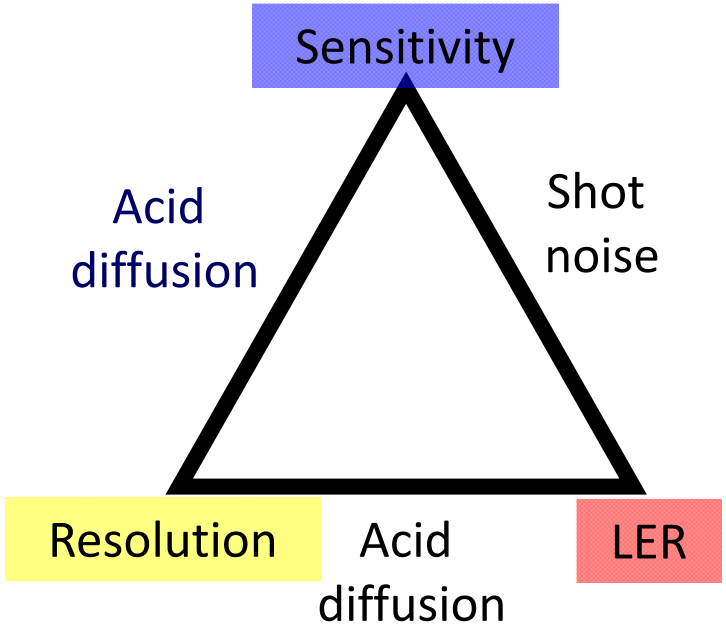
Issue of EUV Resist Development

Specification of 22 nm node

Sensitivity $\leqq$ 10 mJ/cm^2

LWR $\leqq$ 2 nm (3σ)

Total Outgas $\leqq 5 \times 10^{13}$ molecules/cm^2/s



Development of LER reduction and high sensitive resist is most significant issue.

EUV Interference Lithography for the resist evaluation of 1X nm node and below

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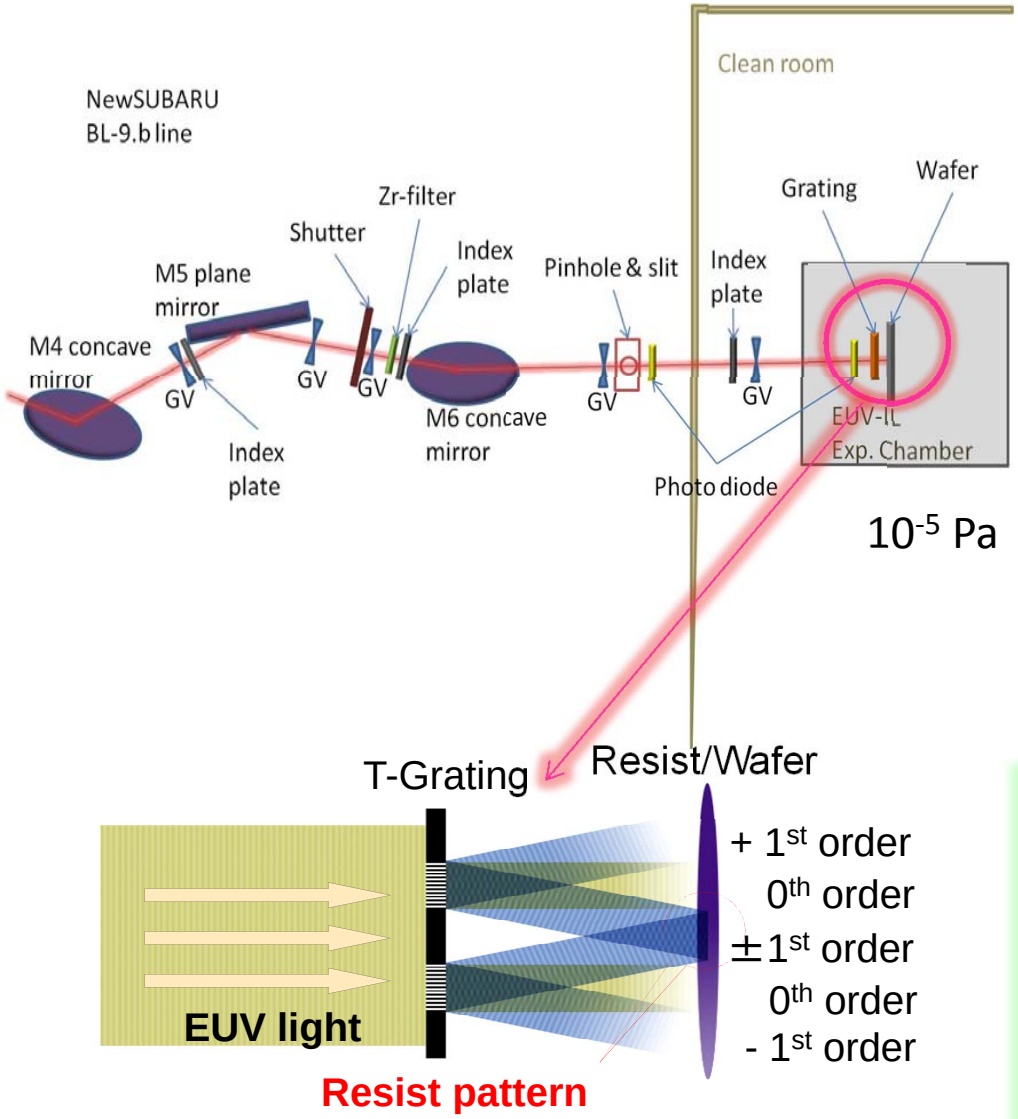
EUV Interference Lithography



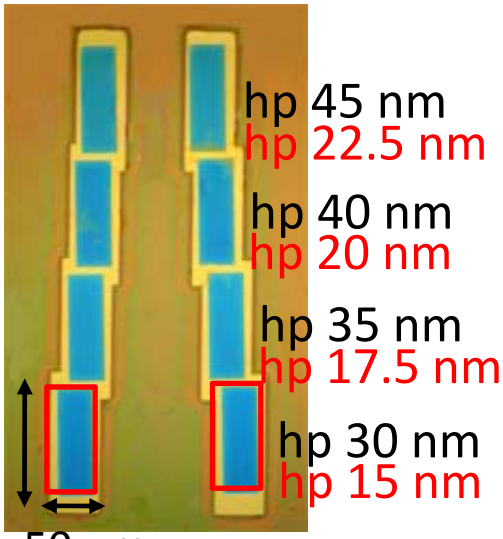
Exposure tool

Clean room
Class 100

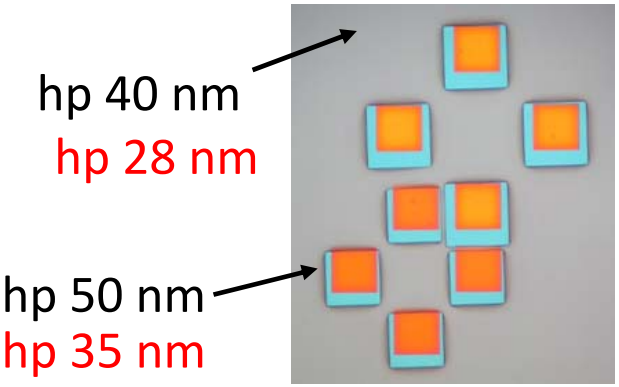
■The Interference fringes were created at the interference point of 1st order and -1st order diffracted lights.

■ Replication pattern pitch of the resist pattern has a half pitch size of the diffraction grating.

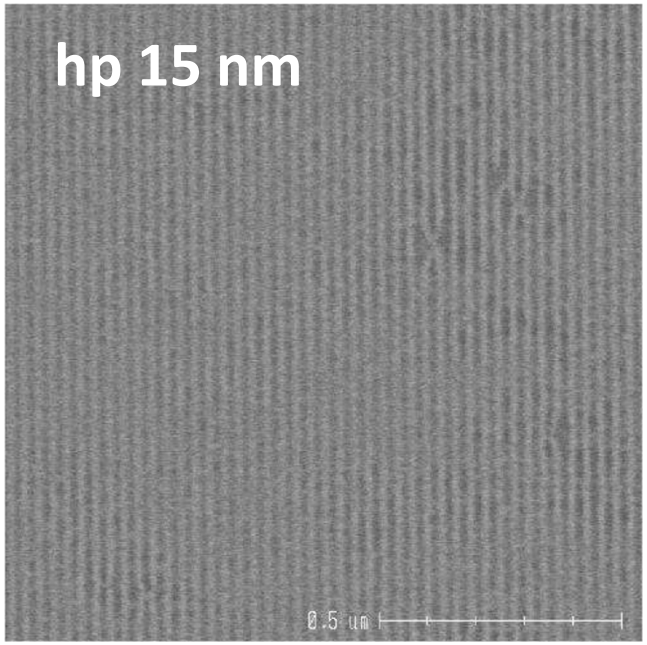
Resist replication results

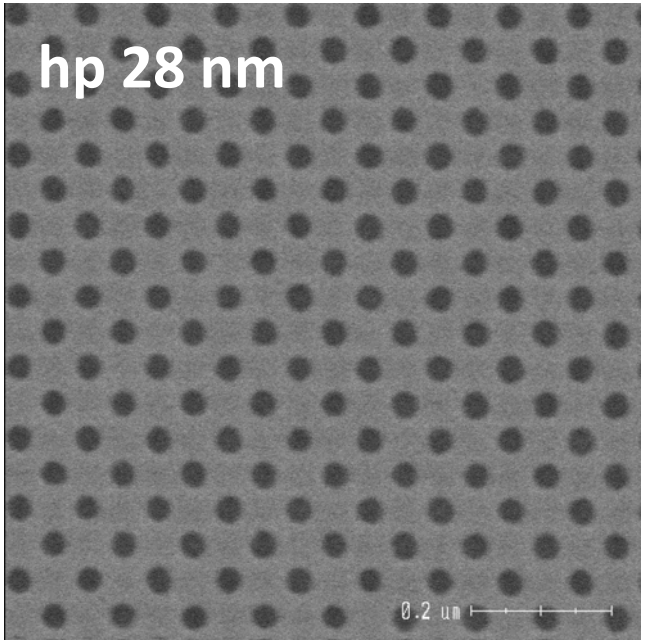


Two window transmission grating

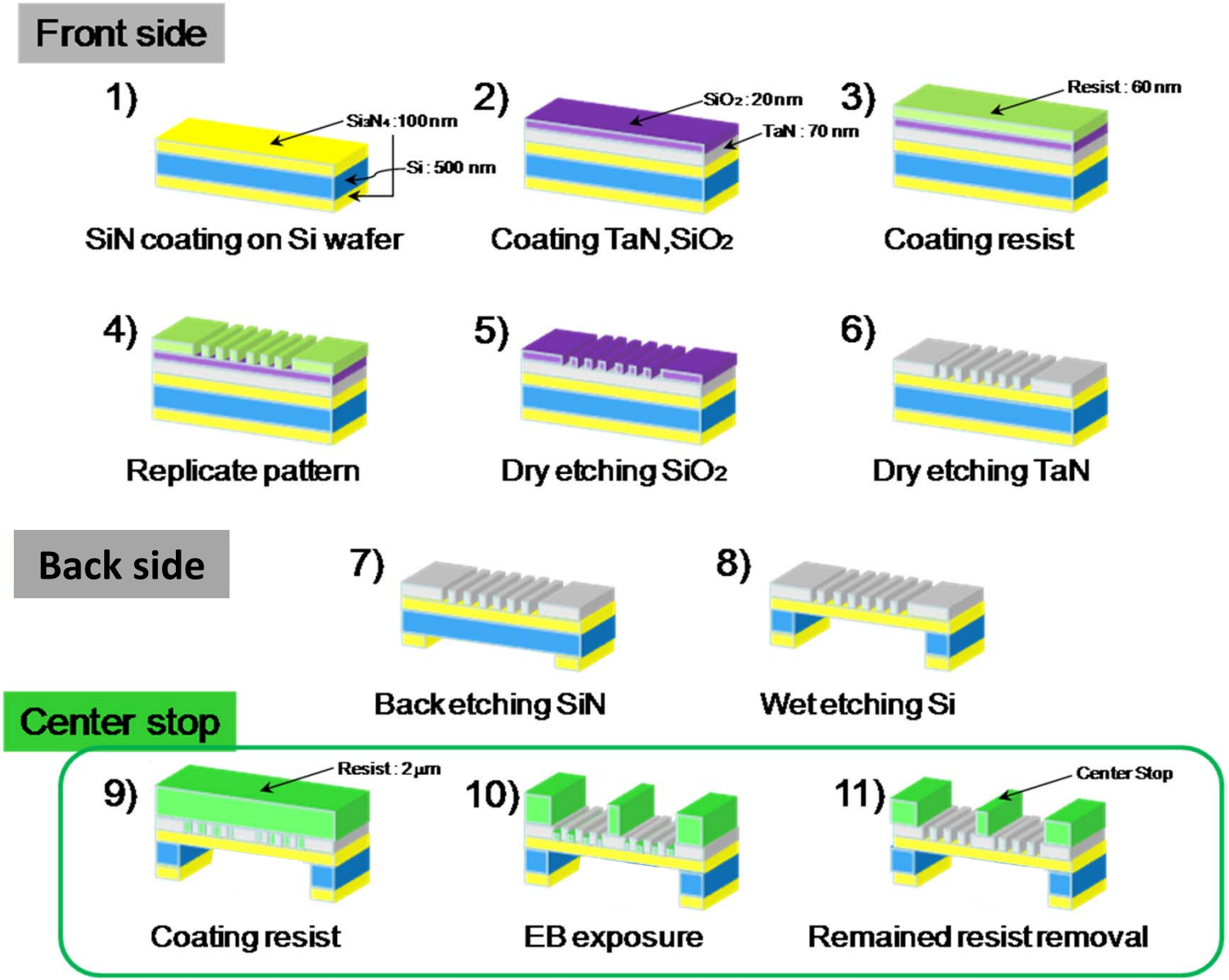


Four window transmission grating

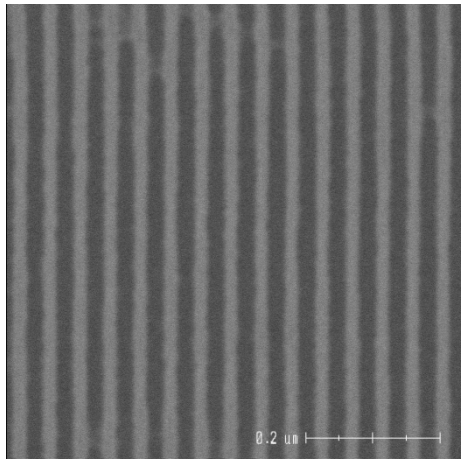




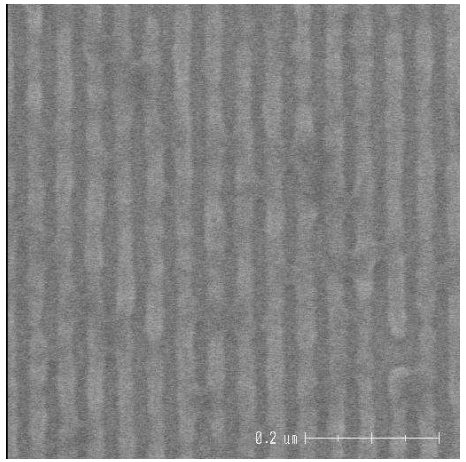
Fabrication of the transmission diffraction grating



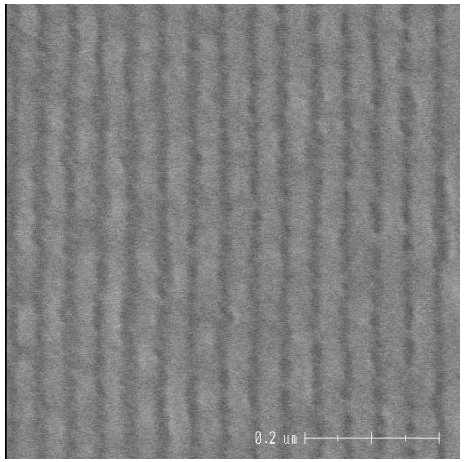
Resist evalutaion results using EUV-IL at Center for EUVL (20 nm L/S) SEM images (@X200k)



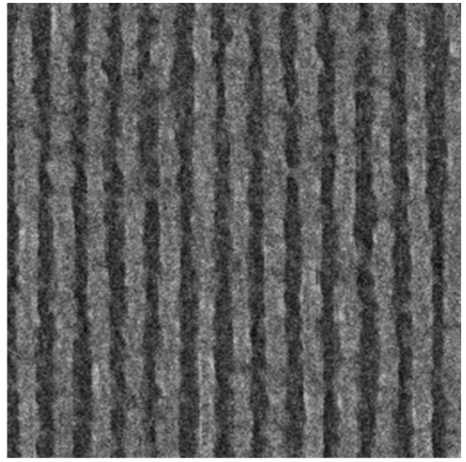
Resist A



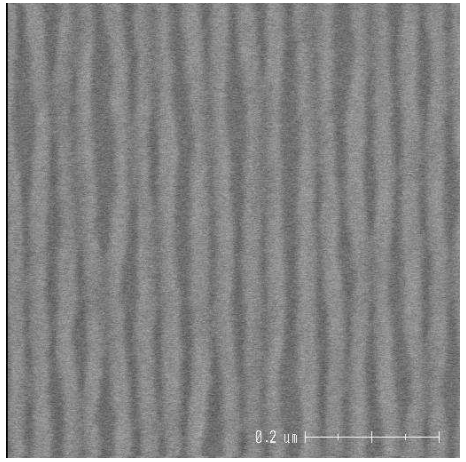
Resist B



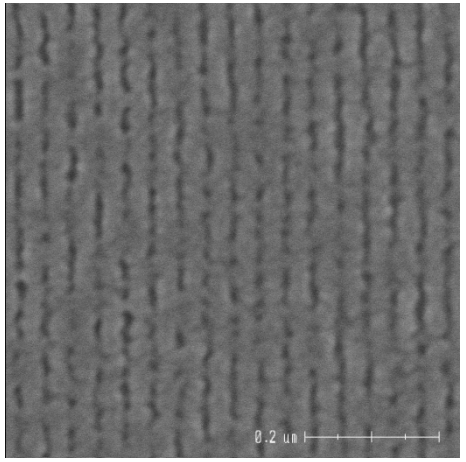
Resist C



Resist D

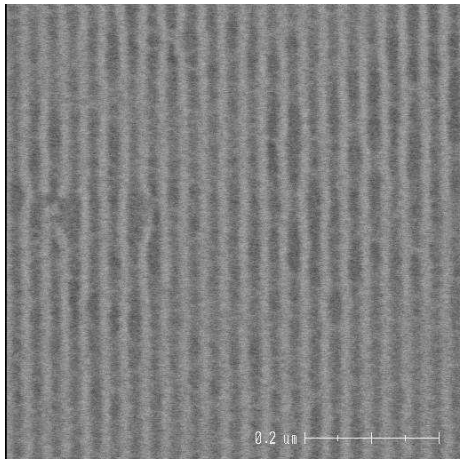


Resist E

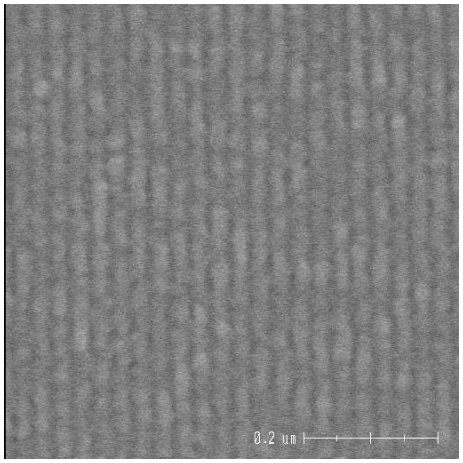


Resist F

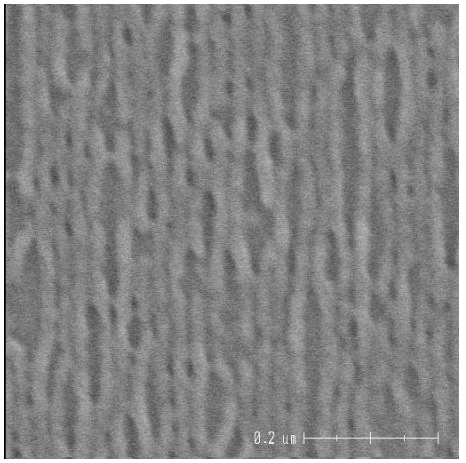
Resist evalutaion results using EUV-IL at Center for EUVL (15 nm L/S) SEM images (@X200k)



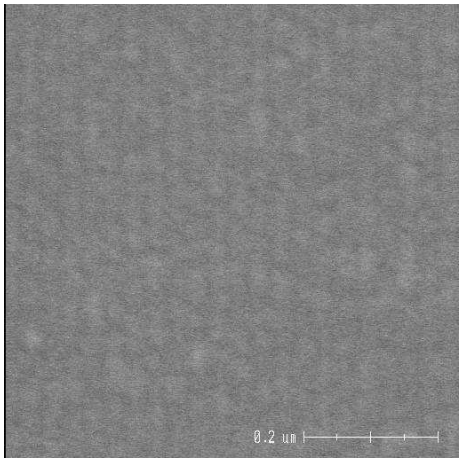
Resist A



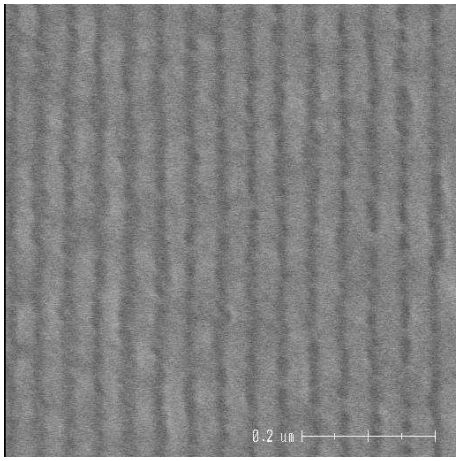
Resist B



Resist E



Resist C



Resist G

Conclusions

1) The transmission grating with 30 nm L/S was succeeded with fabrication.

2) The vibration displacement was reduced to be 5 nm in maximum.

3) hp 15 nm L/S pattern and hp 28 nm hole pattern was replicated.

4) The EUV-IL is to open use for evaluation of resist for 1X nm in EUVL to accelerate resist development.

Near future plan

1) In the near future, for hp 11 nm resist patterning, fabrication of the transmission gratings would be improved, and we will realize evaluation of EUV resist for 11 nm.

2) We will evaluate various type of EUV resists.

Acknowledgments

1) We would like to thank Dr. Andrew Grenville and Dr. Jason Stowers of Inpria Corporation for their support to provide the resist materials.

2) This research is supported by Research Fellow of the Japan Society for the Promotion of Science.

SR Absorption Spectroscopy for the Chemical Reaction Analysis of EUV Resist

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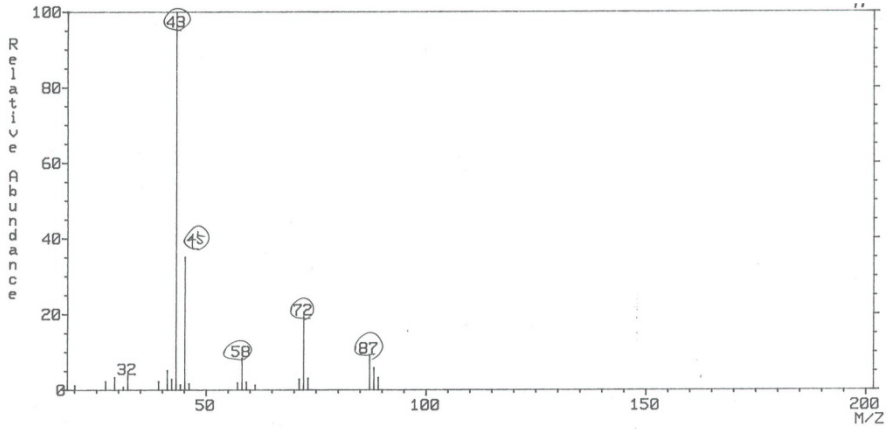
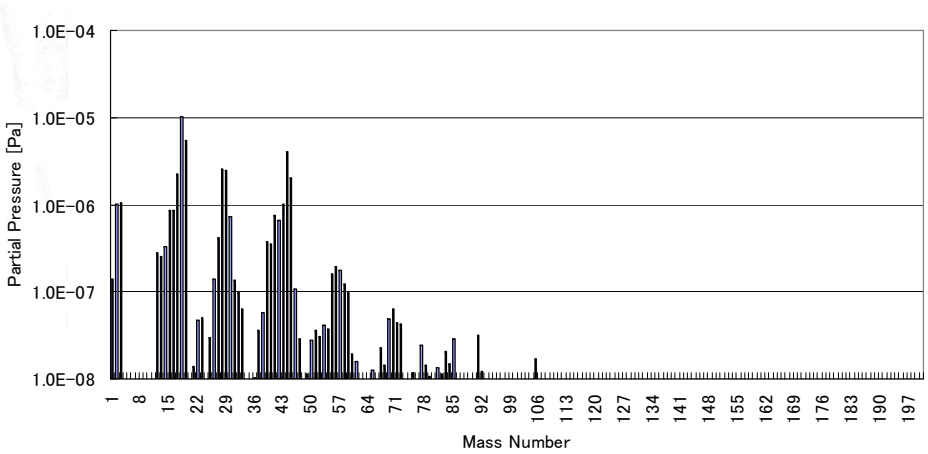
[1)]University of Hyogo
[2)]Tokyo Ohka Kogyo

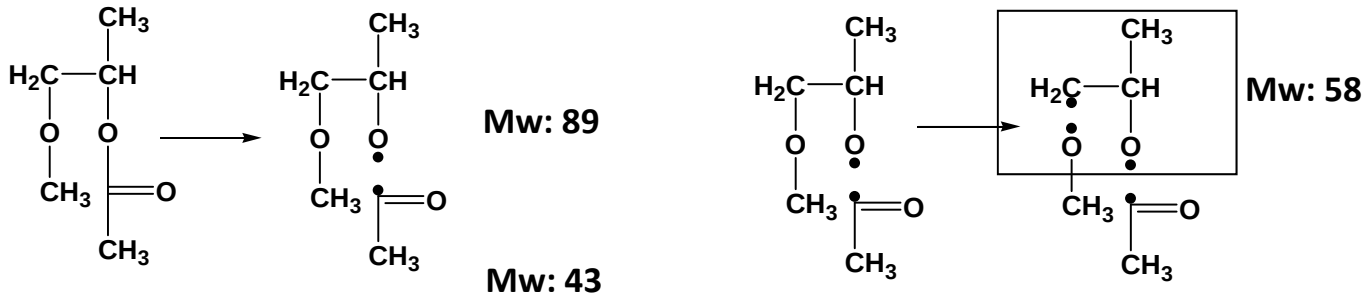
PGMEA Decomposition Reaction under EUV exposure



(a) Fragments from GC-mass

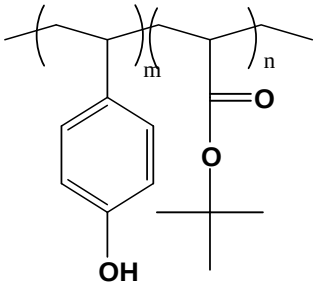
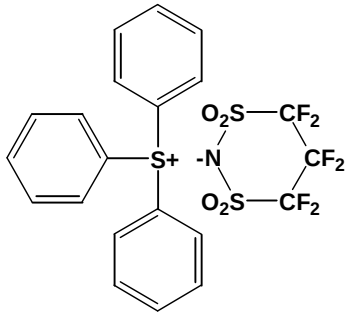
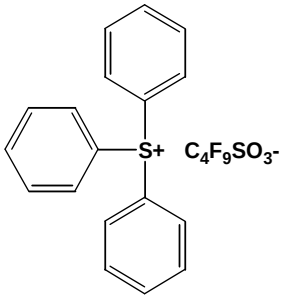
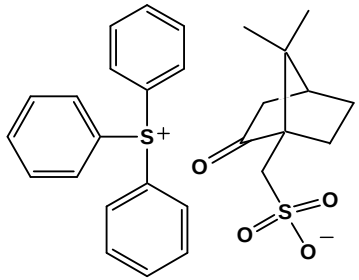


(b) Partial pressure displacement

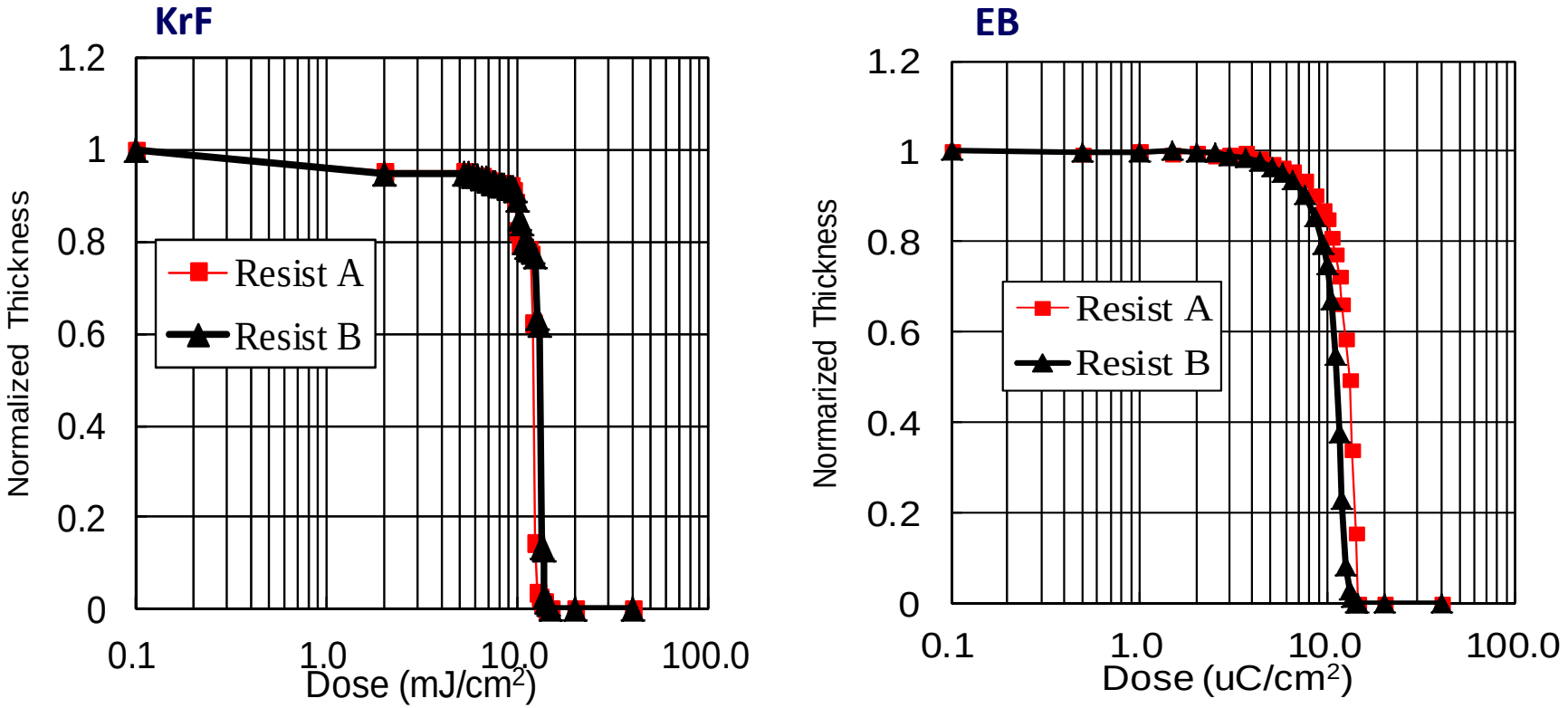


(c) Decomposition reaction of PGMEA in resist

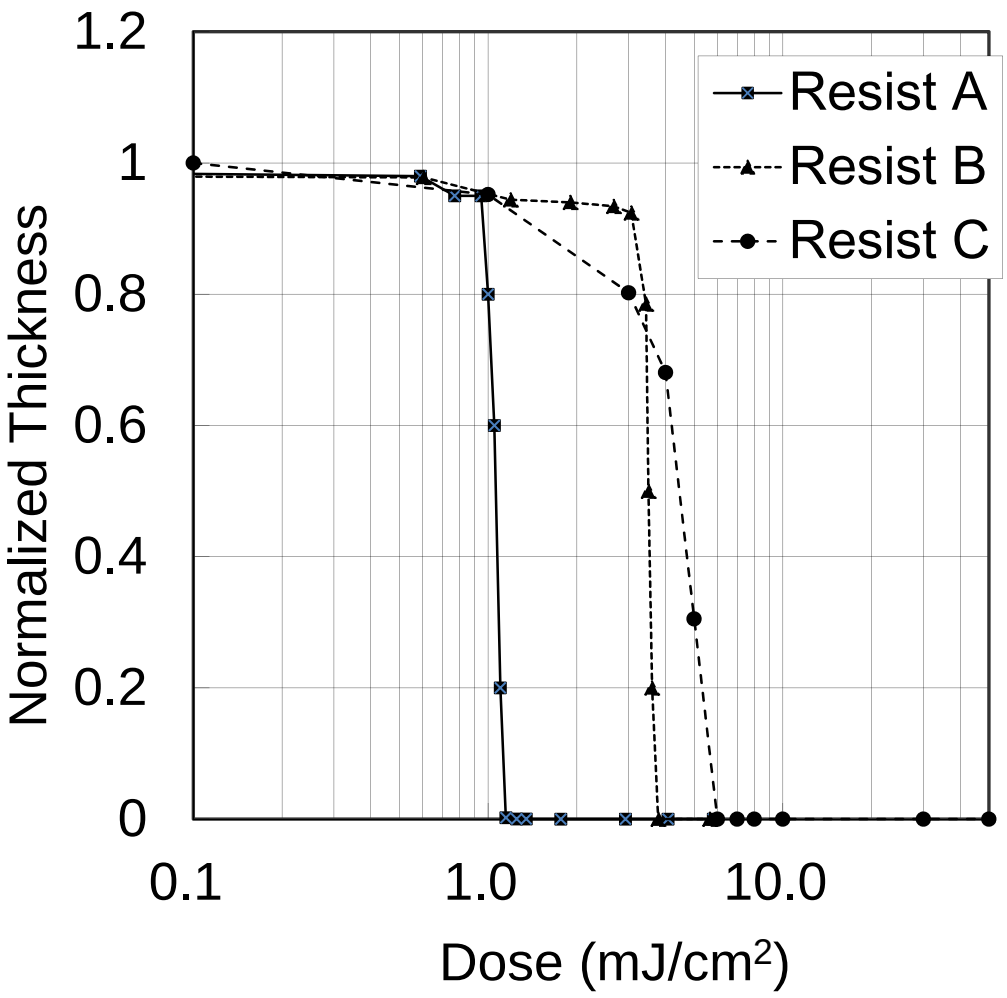
Model resist employed in this study

Sample	Resist A	Resist B	Resist C
Base polymer	 poly (vinylphenol-co-tert butylacrylate)		
PAG	TPS-Imidate 	TPS-Nonaflate (10 wt% Ref.) 	TPS-Cs 
Solvent	propylene glycol monomethylether acetate (PGMEA)		

Sensitivity difference under KrF, and EB exposures

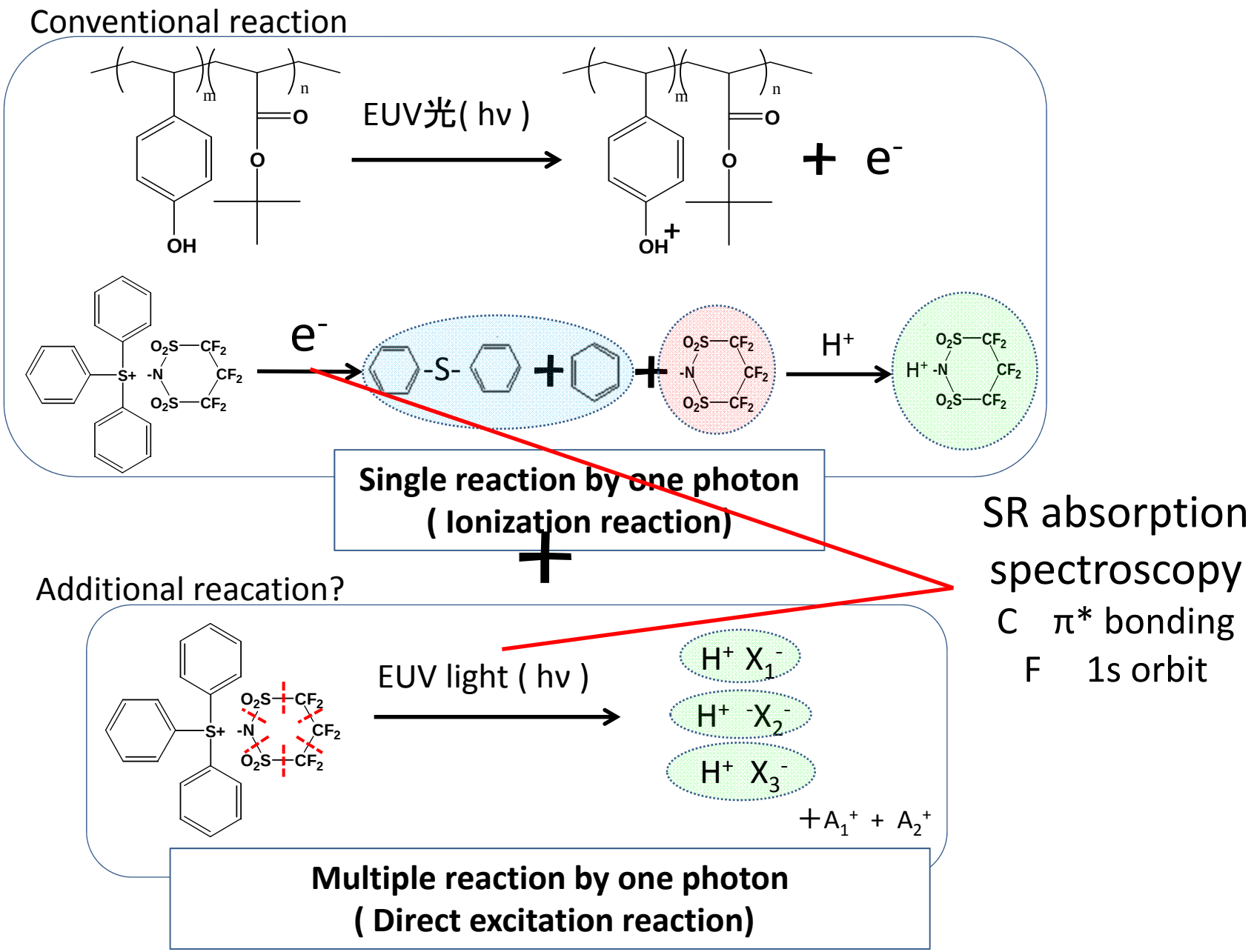


Sensitivity difference under EUV exposures

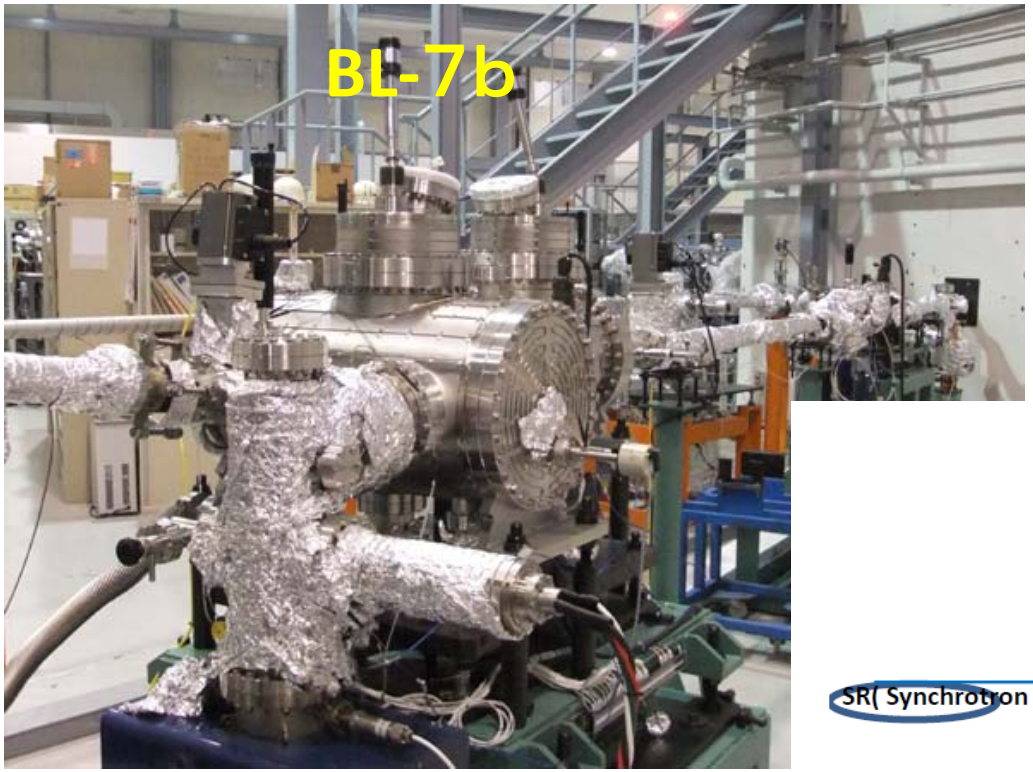


Sample	E_0 Sensitivity
Resist A	1.1 mJ/cm²
Resist B	3.8 mJ/cm²
Resist C	6.0 mJ/cm²

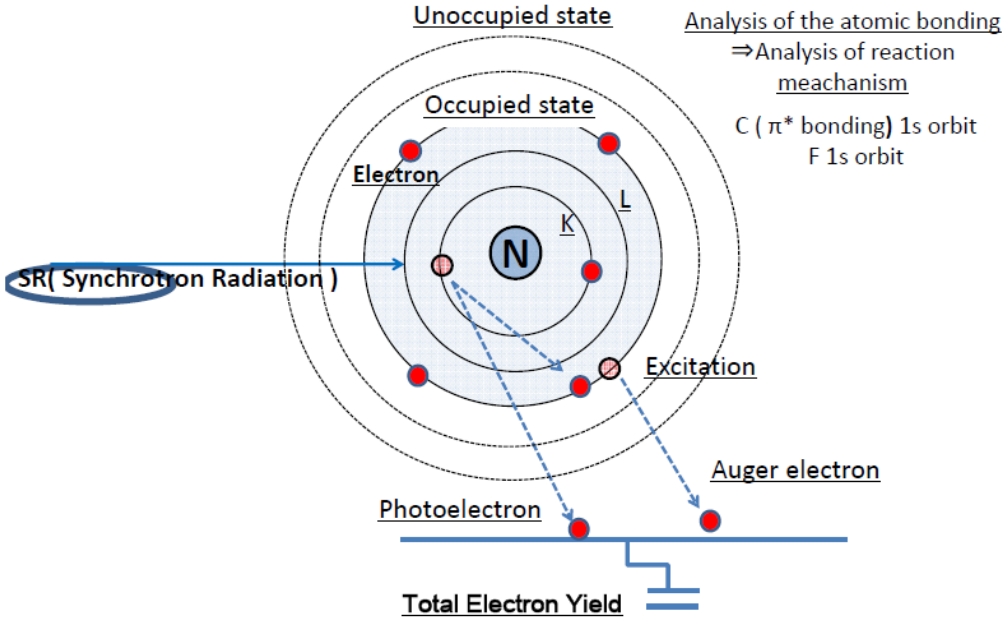
Why the sensitivity different?



Resist chemical reaction study by SR absorption spectroscopy for high sensitivity and low LWR



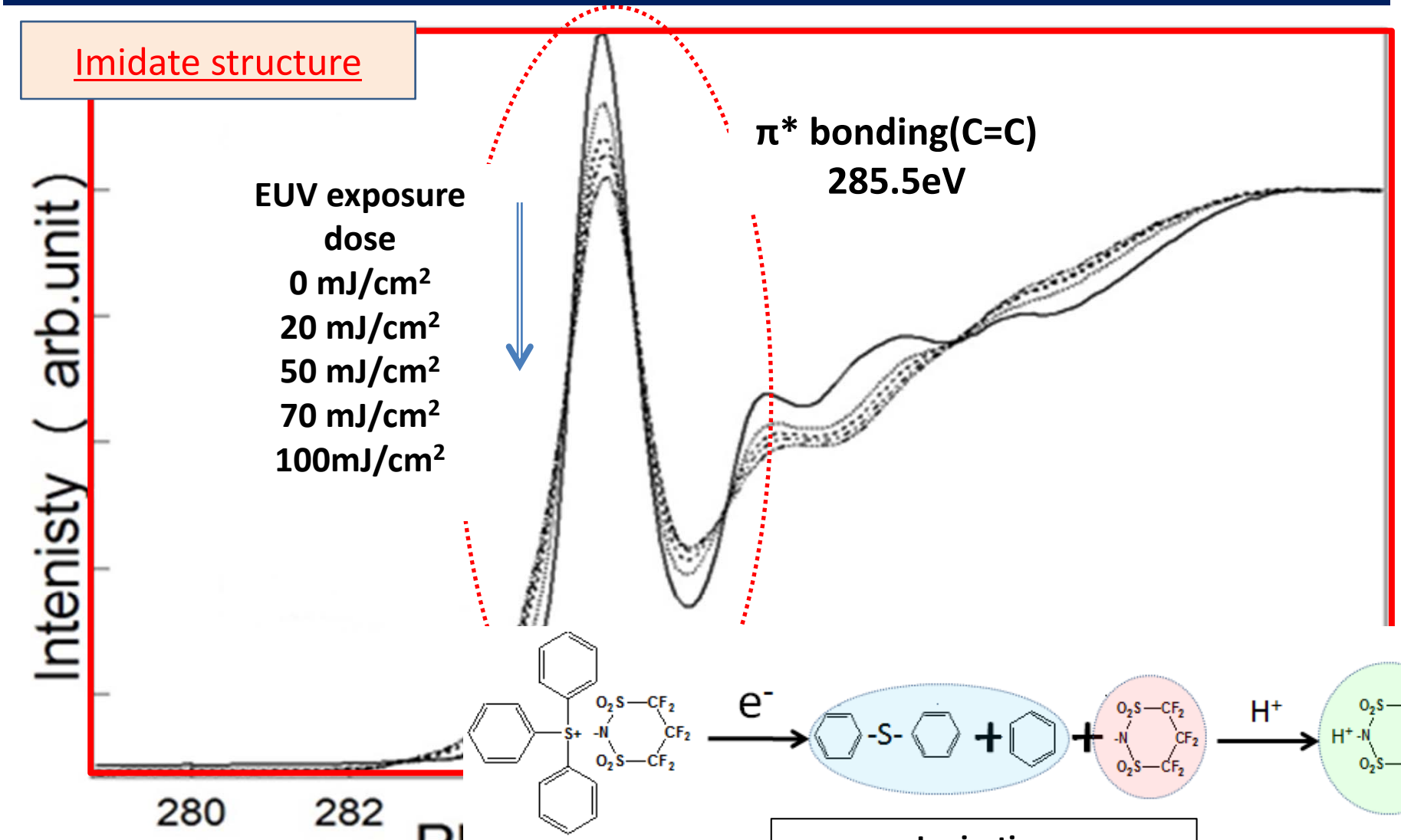
World first analysis for chemical reaction of EUV resist!!



Energy Resolution
E/ΔE=～3000

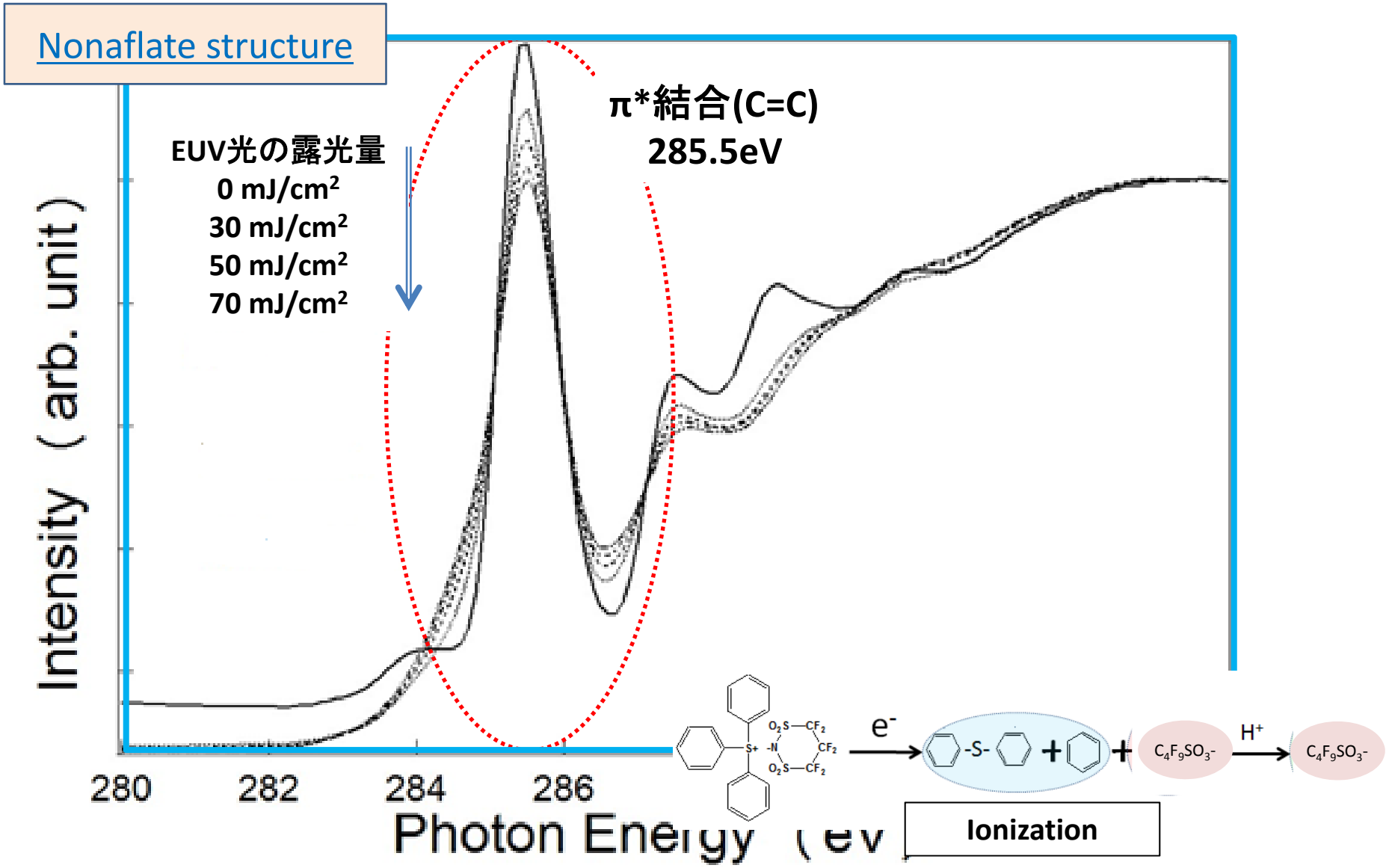
Decomposition reaction of cation in TPS-Imidate employed as the PAG

Imidate structure



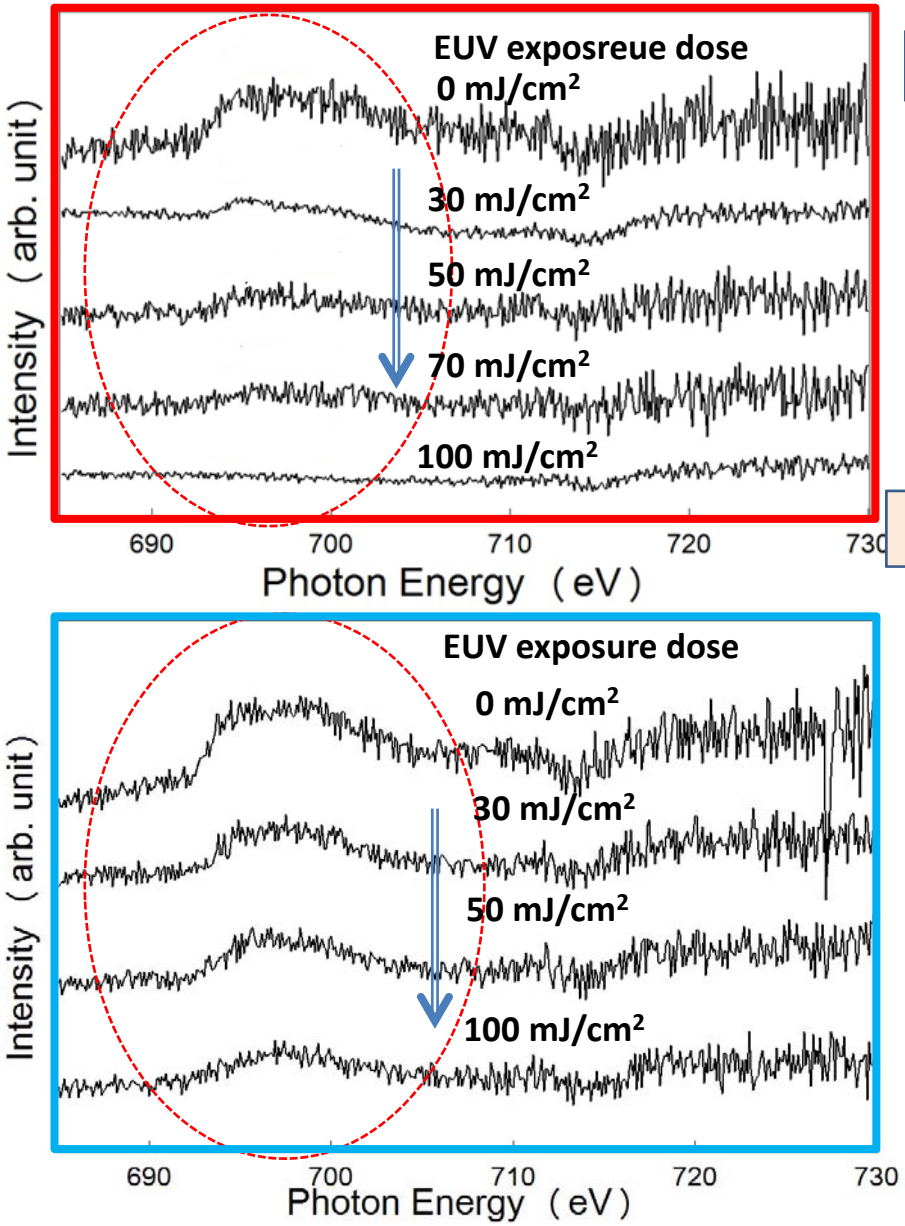
Ionization
(single reaction by one photon)

Decomposition reaction for cation in TPS-Nonaflate employed as the PAG

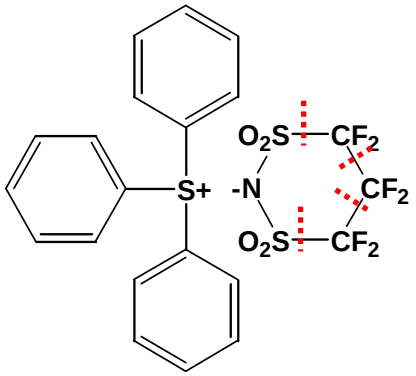


Anion decompostion differences in Imidate and Nonaflate

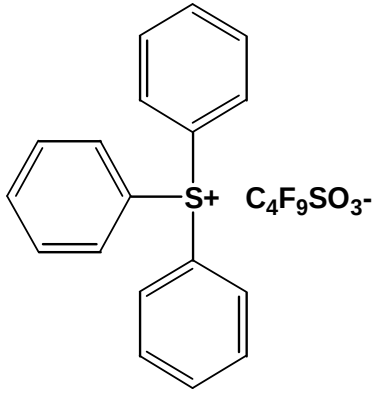
F 1s



Imidate structure



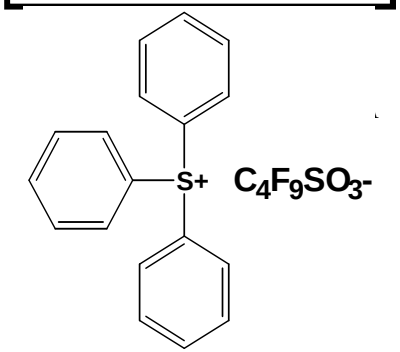
Nonaflate structure



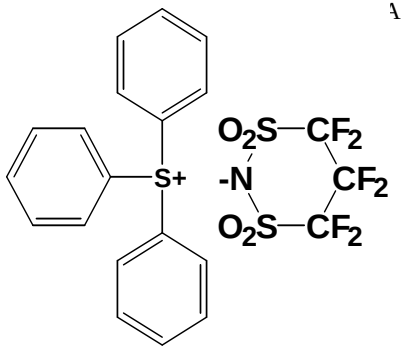
Anion of Imidate is easier to decompose than that of Nonaflate.

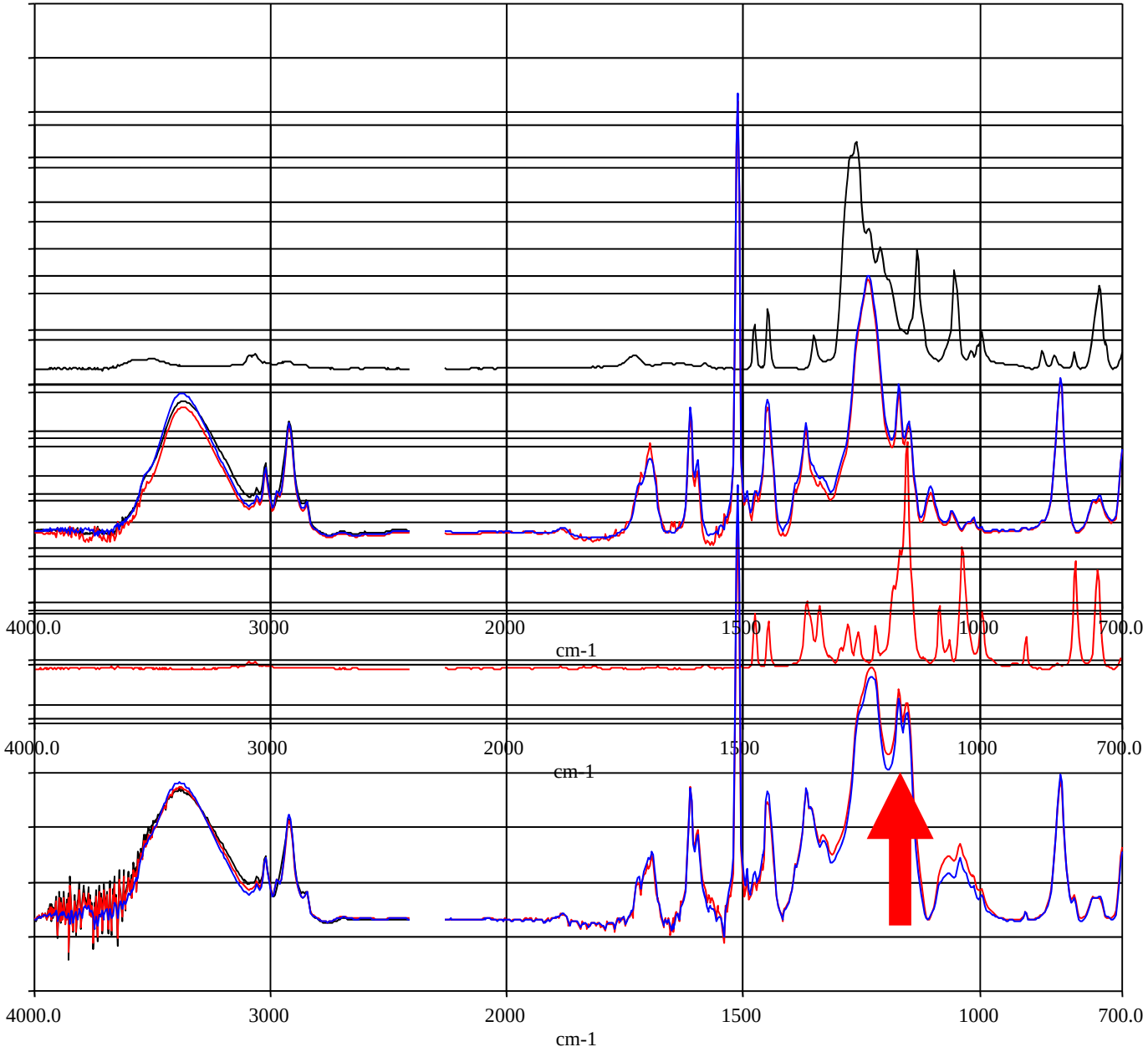
FT-IR spectra of Resists A and B

Resist B

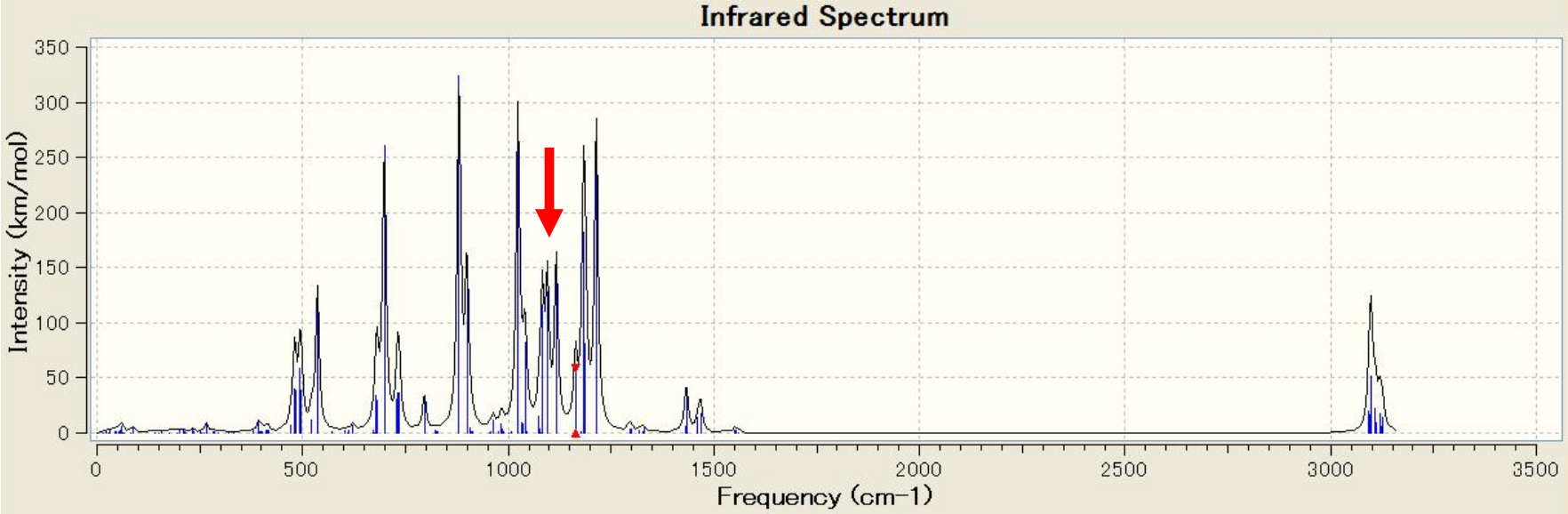


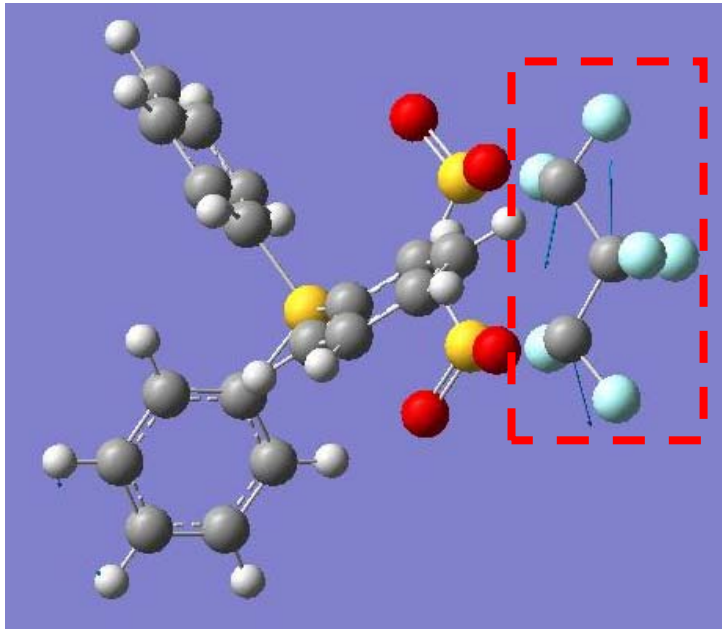
Resist A





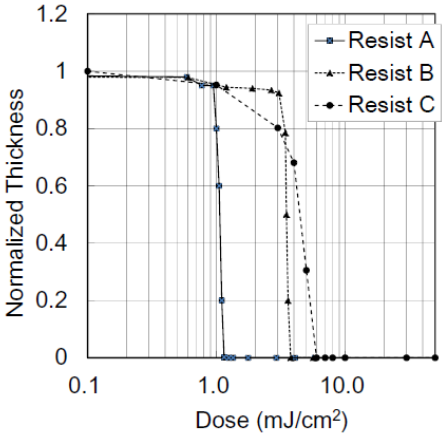
The computation results of infrared spectrum by the electron orbital perturbation theory using the software code Gaussian04



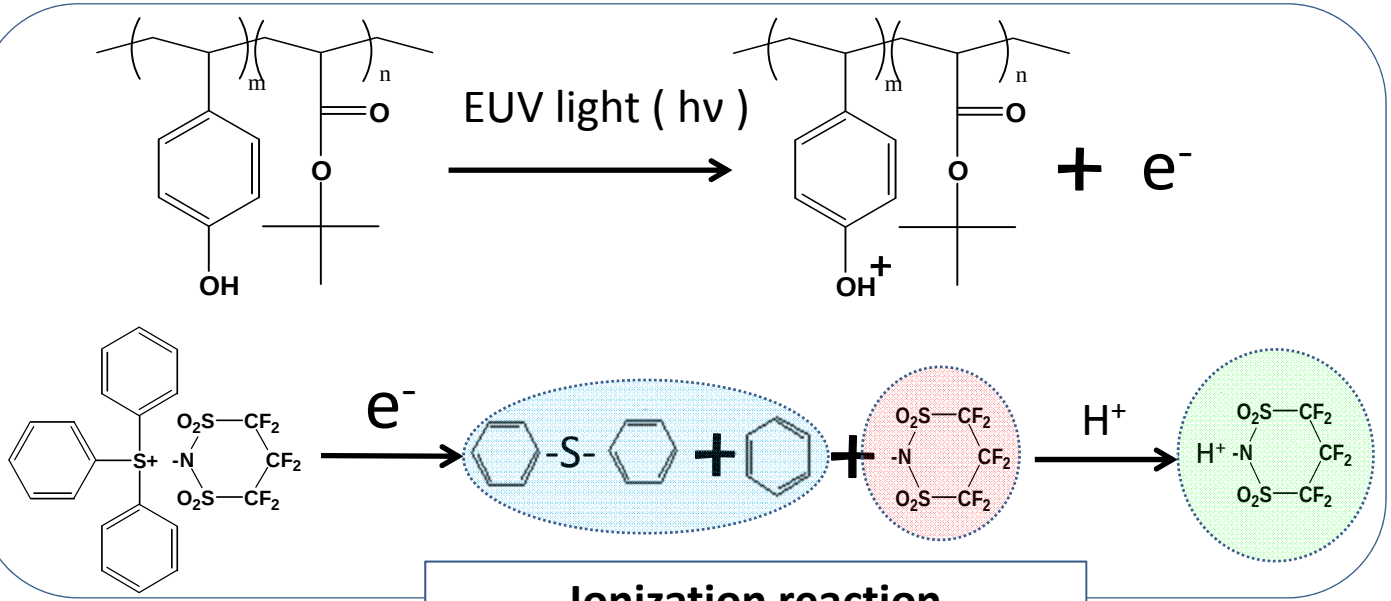


Assumption was proved!!

Why 4 times high sensitive in Imidate type of PAG under EUV exposure??

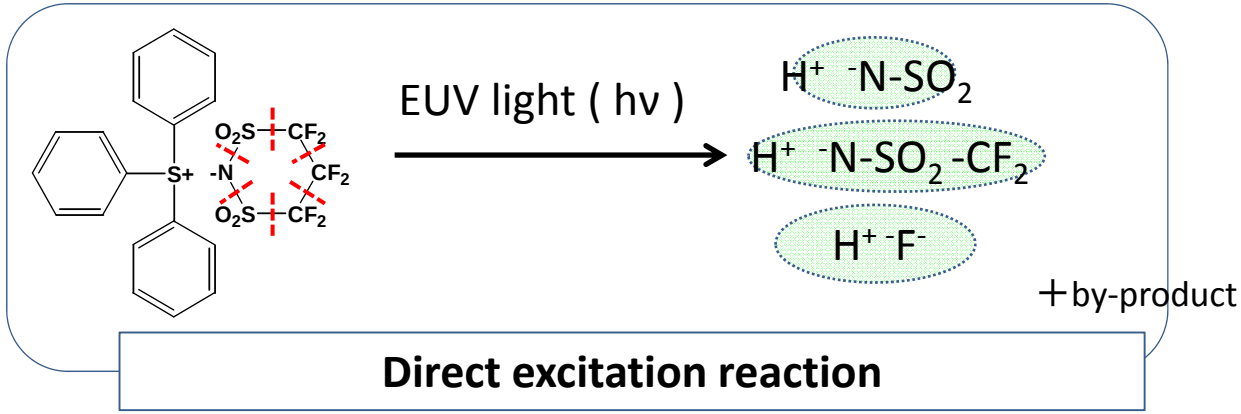


Conventional reaction



+

Additional reaction



Conclusion

1) The CA resist which employed TPS-Imidate as PAG has higher sensitivity comparison to that of TPS-Nonaflate.

2) The reaction SR absorption spectroscopy indicate that as for the absorption changes of fluorine 1s core level, the Imidate employed as the anion of PAG is decomposed under EUV exposure. This means that the additional acid is generated to increase the acid yield.

3) The reaction indicated above is agree with the outgassing analysis for the TPS-Imidate.

Summary

1. EUV interference lithography

Using EUV-IL 15nm hp was replicated. And EUV-IL lithographic tool has a capability to evaluate EUV resist material for 1x nm node.

2. SR absorption spectroscopy for the chemical reaction analysis for EUV resist

1) The resist employed TPS-Imidate as PAG is approximately four times higher than that as TPS-Nonaflate.

2) The reaction SR absorption spectroscopy indicate that

as for the absorption changes of fluorine 1s core level, the Imidate employed as the anion of PAG is decomposed under EUV exposure. This means that the additional acid is generated to increase the acid yield.